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Environmental Health Center
Cincinnati, Ohio

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THE BACKGROUND RADIOACTIVITY OF WATER AND BIOTA OF THE SAVANNAH RIVER (1951-1952)

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In the Environmental Health Center survey of the Savannah River in 1951-1952, 32 water, 282 fresh water biota, and 438 estuarine biota samples were collected and analyzed by duplicate for the assay of gross alpha and beta radioactivity. Radioactive assays were made on the dissolved and suspended solids of water samples and the flesh and bony tissues of the biological samples.

Radioactivity of Water

The procedure used for assaying the radioactivity in fresh water was as follows:

1. Suspended Solids

   a. Filter 900 ml. of well mixed water sample through a membrane filter(*). Save the filtrate for Part 2. Allow the membrane plus the suspended solids to dry for several hours at room temperature before counting.

   b. Place the membrane filter in an aluminum dish. Insert an iron ring at the periphery of the filter to hold it flat. Insert sample into an internal proportional gas-flow counter set at a voltage for alpha counting. Purge with P-10 gas and count for 10 minutes. Pass the instrument and count for an additional 10 minutes. If the 10 minute counts do not agree within the statistical error of counting, repeat the count. Repeat the counting procedure in an internal counter set at a voltage for beta counting. Correct for background and geometry and convert the values to $\mu\mu c$/liter of water.

(*) Clark, H. W., Gelfreich, E. E., Peter, H. L., and Kabler, P. W. "Membrane Filter in Sanitary Bacteriology". Public Health Reports 66, 391 (1951).

2. Dissolved Solids

a. Place aluminum dishes (48 mm. in diameter and 15 ml. in capacity) in an oven at 103° C. for two hours. Cool in a desicator and weigh.

b. Evaporate duplicate 200 ml. portions of the filtered sample from Part 1 in duplicate weighed aluminum dishes on a hot plate which has been adjusted to keep the temperature slightly under the boiling point of the water.

c. Dry the samples at 103 - 105°C. to constant weight.

d. Place dish in internal counters and count for two 16 minute periods at a voltage for alpha counting and again at the beta counting voltage as for suspended solids. Convert the alpha and beta counts to μμc/liter of water.

Five water samples were tested in August 1951, when membrane filters were not available. The analyses were similar except that one liter of water was filtered through a 5.5 cm. Whatman No. 5 filter paper in a small Buchner funnel. The suspended solids retained on the paper were dried with infra-red lamps and counted in the internal proportional counter.

3. Results

The results of the alpha and beta radioactivity assays of the suspended solids and in solution in the water samples are presented in Table 7. The radioactivity is reported in micromicrocuries per liter plus or minus a precision of measurement equal to two standard deviations. The table contains one early sample, August 14, 1951, at station S-203.3 which had an unusually high alpha and beta activity. These results were included in the Table 7, but have been rejected from further consideration.

In discussing the radioactivity of water samples, it is convenient to refer to the radioactivity associated with the suspended solids as insoluble activity and the activity of the filtrate or dissolved solids as soluble activity.

The suspended solids alpha activity shown in Table 7 varied from zero to a maximum of 4.1 ± 1.7 micromicrocuries per liter of water. The soluble alpha activity of the sample containing the maximum suspended activity was 0.1 ± 1.1 μμc/liter. Thus the total alpha activity of this sample was 4.2 ± 2.0 μμc/liter of water. Usually there was more insoluble than soluble alpha activity. However, in six out of 31 samples, the soluble alpha activity exceeded that in the suspended solids. The maximum soluble alpha activity was 8.4 ± 2.1 μμc/l. compared to 0.4 μμc/l. for the suspended solids fraction.

Table 7

RADIOACTIVITY OF SAVANNAH RIVER WATER SAMPLES

Location (River Mile)	Date Collected	Alpha Activity				Beta Activity			
		Suspended		Dissolved		Suspended		Dissolved	
		μμc/l	± μμc/l	μμc/l	± μμc/l	μμc/l	± μμc/l	μμc/l	± μμc/l
UTR*	12-28-51	3.1	5.9	-0.1	1.1	8.6	5.1	31.8	14.8
UTR*	10-23-51	0.8	0.6	0	1.3	5.7	5.0	2.5	10.8
LTR*	12-3-51	0.4	0.6	0	1.3	0	5.2	5.6	10.0
LTR*	2-6-52	0.7	0.5	0.0	1.2	-0.4	4.4	-4.9	9.2
ST*	11-7-51	0.2	0.1	0.2	0.5	1.5	0.6	-0.8	3.5
ST*	2-6-52	0.9	0.6	0.4	1.1	-0.7	4.4	10.5	9.2
Fo*	11-7-51	0.2	0.1	0.2	0.5	1.0	1.1	-2.9	3.4
Fo*	1-23-52	0.1	0.4	0.7	0.8	-2.1	4.8	-3.4	7.4
Fo*	2-18-52	1.0	0.7	-0.3	1.6	4.0	4.4	3.4	10.8
218.5	8-13-51	0.2	0.2	4.4	1.5	0.0	3.2	1.0	16.0
218.5	1-8-52	1.2	1.1	-0.3	1.2	10.8	10.1	7.7	7.7
215.6	8-13-51	0.0	0.2	0.0	1.1	0.0	3.2	12.4	16.0
203.3	8-14-51	4.5	0.6	24.7	4.2	0.0	3.2	50.6	17.2
202.9	12-18-51	0.6	0.6	0.4	1.2	5.7	5.0	2.5	10.8
202.9	2-13-52	0.8	0.7	0.3	1.6	3.8	4.3	8.9	10.5
202.9	3-14-52	2.3	1.0	1.0	1.2	0.2	4.4	23.1	9.8
197	12-18-51	0.3	0.6	0.2	1.2	1.1	6.3	5.3	9.7
197	2-13-52	1.4	0.7	0.4	1.1	2.3	4.4	18.5	10.8
189	8-2-51	0.4	0.4	8.4	2.1	0.0	3.2	0	16.0
172	10-23-51	0.3	0.6	0.8	1.6	0	5.1	4.4	10.3
172	12-28-51	3.9	1.5	1.6	2.6	6.2	4.1	6.8	29.0
172	4-3-52	1.2	0.8	0.5	1.5	12.3	4.6	12.6	10.5
167	8-2-51	0.3	0.2	0.4	1.1	0.0	3.2	0	16.0
152	12-3-51	0	0.5	0	1.6	0	5.2	0	11.5
152	1-9-52	4.1	1.7	0.1	1.1	5.2	8.9	-3.7	7.7
152	4-3-52	1.3	0.7	-1.7	2.2	13.2	6.3	12.6	11.1
52	12-6-51	0.8	0.6	0	1.4	2.9	5.2	0	10.9
52	2-20-52	1.7	0.8	0.0	1.2	3.8	4.3	0.0	10.5
52	4-9-52	1.4	0.7	2.5	2.3	-4.6	6.0	13.2	11.1
11	12-6-51	0.4	0.6	0	11.3	0	5.2	96.	86.
11	3-12-52	0.9	0.7	0.0	9.6	5.9	4.3	-5.	76.
11	4-9-52	1.4	0.7	0.2	1.4	-4.2	6.0	3.7	11.1

*UTR - Upper Three Runs; LTR - Lower Three Runs;
ST - Steel Creek; Fo - Four-Mile Branch.

In those samples having a measurable alpha activity, the beta activity was appreciably higher in magnitude than the alpha activity. This is particularly true with respect to soluble activity. Thus the maximum soluble beta activity was 31.8 ± 14.8 μμc/l. This sample had 8.6 ± 5.6 μμc/l. of insoluble beta activity and the maximum total beta activity of all samples (40.4 ± 15.6 μμc/l.).

The Radioactivity of Fresh Water Biota

The biological samples consist of bone and flesh samples of large fish, whole organisms of minnows, insect larvae and algae. The samples were selected, weighed and stored in vials in the field laboratory. Some samples were also composited in the field. The perishable samples were frozen, packed in dry ice and shipped air express to Cincinnati. The samples were kept in a frozen condition until analyzed.

The laboratory processing procedure is as follows:

1. Fish Flesh.

A composite sample of 10 fishes is dissolved in 50 ml. of 1:1 nitric acid. In the case of composite samples an aliquot equal to 1 to 2 grams of weighed fish, or in the case of an individual specimen one or two grams of weighed fish flesh is transferred to a 50 ml. Erlenmeyer flask with about 5 ml. of distilled water and 5 ml. of concentrated nitric acid. The sample is gradually heated to boiling on a hot plate and evaporated to dryness. About 10 ml. of concentrated nitric acid is added and the solution warmed to about 50° C. Hydrogen peroxide (30 percent solution) is added dropwise, as required, to decolorize and promote wet oxidation. Digestion is continued at a gentle boiling temperature to dryness. The latter steps are repeated if necessary, until the residual solids in the flask are white and crystalline in nature. The acid digested mineral residue represents one to two percent of the weight of the flesh. The residue is dissolved in a known volume of 0.5 milliequivalents of nitric acid and 7 to 10 ml. of water. It is convenient to prepare this clear digestate volume so that 2 ml. contains 0.2 or 0.4 gram of original tissue. A sample for counting is then prepared by compositing 2 ml. from each of two to five digestates in an aluminum dish and evaporating gently to dryness. The white crystalline solids are distributed fairly uniformly over the dish bottom. The sample is then counted for alpha and beta radioactivity as explained previously for water samples and reported in μμc/gram of original tissue. If the composite sample shows the presence of alpha or beta activity above a statistically normalized average, a sample of each of the digestates is deposited on an aluminum dish and counted separately.

2. Fish Bone

Bony tissue is removed from fish specimen, air dried, scraped free of flesh and stored in vials at the field laboratory and shipped to Cincinnati. Preliminary determinations of these fish bone samples indicate a wide fluctuation in the moisture content, probably due to variable preparation, shipping and storage conditions. Consequently, composite samples of 5 to 10 grams of bone are ignited in a tared crucible at 450° C. for at least four hours, cooled and weighed. The ignited bone sample is then ground to a powder in a mortar. One gram of bone powder is transferred to an Erlenmeyer flask and dissolved in about 2 ml. of warm one molar nitric acid. After solution, the volume is diluted with water so that each ml. contains 5.0 mg. of bone ash. Five to 10 ml. of solution is transferred to an aluminum dish, evaporated gently to dryness and counted. Small samples of about one gram of bone are similarly ignited in a tared crucible, weighed and dissolved without grinding.

3. Brush Box Organisms and Algae

These samples are treated similarly to fish flesh samples. In general, the samples required longer periods of acid digestion and the residues are frequently colored and difficult to dissolve in dilute nitric acid after wet oxidation. Suspensions of the residue are transferred to aluminum dishes and counted.

The procedures adopted for low level assay of biological samples may cause the loss of some radioactivity such as carbon, iodine and gases. The loss of small amounts of this radioactivity is considered to be relatively unimportant from a public health standpoint. The results include natural potassium-40 which might conceivably increase the fish flesh beta radioactivity by as much as 3 μμc/gram.

4. Results

The radioactivity of the flesh and bony tissue of 40 individual or composite fish samples is presented in Table 8. The radioactivity of 7 composite samples of minnows and 5 algae samples is presented in Table 9 and the radioactivity of 17 samples of brush box organisms (largely fly larvae) is presented in Table 10. The results in these tables showed that the radioactivity of all samples exclusive of fish bone was less than 4.8 ± 3.9 μμc of alpha activity andless than 14.3 ± 5.6 μμc of beta activity per gram of wet weight sample. The minnows (whole fish samples) and the fly larvae, all of which probably contained native soil, showed a significant alpha activity. The algae showed no significant amount of alpha activity, but a measurable beta activity. The maximum alpha activity of fish flesh was 1.5 ± 0.9 μμc/g. The radioactivity of the ash of fish bone was less than the statistical error of the determination which varied from ± 2 to ± 28 μμc/gram for the alpha activity and ± 20 to ± 260 μμc/g. for beta activity.

Table 8

The Radioactivity of Fresh Water Fish

Savannah River 1951-1952

Specimen		Station River Mile	Month Collected	Radioactivity of flesh(1)				Radioactivity of bone(2)			
Kind	Numbers per Sample			Alpha μμc/g ± μμc/g		Beta μμc/g ± μμc/g		Alpha μμc/g ± μμc/g		Beta μμc/g ± μμc/g	
Gar Family											
Lepisosteus osseus	3	146.4	Jan.	0.2	0.4	1.4	3.7	-0.5	2.7	11.1	21.6
" "	4	146.4	Jan.	0.0	0.2	1.2	1.3	-1.3	2.2	10	22
Bowfin Family											
Amia calva	2	146.4	Jan.	0.0	0.3	1.8	4.3	-	-	-	-
Herring (Shad) Family											
Alosa sapidissima	5	146.4	Jan.	0.0	0.4	0.4	0.3	1.4	2.6	16.7	21.6
Sucker Family											
Minytrema melanops	3	164.7	Jan.	0.5	0.4	-3.5	4.0	-0.9	5.2	-3.2	36
" "	10	137.5	Dec.	0.2	0.4	4.7	6.9	2	25	100	250
" "	1	136.4	Dec.	0.3	0.3	0.8	4.0	6	24	200	210
Moxostoma sp.	1	172.5	Jan.	0.1	0.6	-1.5	4.6	-	-	-	-
" "	1	170.3	Jan.	0.1	0.6	-0.9	5.1	-	-	-	-
" "	5	164.7	Jan.	0.0	0.3	3.4	2.2	5.8	5.8	-21	43
" "	5	164.7	Jan.	0.1	0.3	3.5	2.2	-0.2	4.8	-42	43
" "	1	154.7	Dec.	0.1	0.3	4.3	4.3	-	-	-	-
" "	1	137.5	Dec.	0.1	0.3	7.6	4.6	-5	20	6	250
" "	1	136.4	Dec.	0.0	0.3	2.6	4.6	-8	20	-40	250
Composite A	4		Jan.					0.0	2.0	15	22
Catfish Family											
Ameiurus nebulosus	3	175	Jan.	0.1	0.3	-3.9	3.9	-5.5	4.2	-22	36
" platycephalus	1	172.5	Jan.	1.5	0.9	-3.1	3.9	-	-	-	-
" "	1	171.6	Jan.	0.2	0.2	0.2	1.2	12	13	-	-
" "	3	170.3	Jan.	0.1	0.3	-3.0	4.0	-4.1	4.5	-36	36
Ictalurus catus	1	170.3	Jan.	-0.2	0.6	0.3	5.1	-	-	-	-

Table 8 (Cont'd)

The Radioactivity of Fresh Water Fish

Savannah River 1951-1952

Specimen		Station River Mile	Month Collected	Radioactivity of flesh(1)				Radioactivity of bone(2)			
Kind	Numbers per Sample			Alpha μμc/g±μμc/g		Beta μμc/g±μμc/g		Alpha μμc/g±μμc/g		Beta μμc/g±μμc/g	
Catfish Family (Cont'd)											
Ictalurus lacustris	1	170.3	Jan.	0.1	0.6	-6.8	4.4	-	-	-	-
" "	4	171.6	Jan.	0.0	0.2	-2.0	3.0	-1.7	2.7	-2	27
" "	1	172.5	Jan.	0.1	0.6	-4.9	4.4	-	-	-	-
Ameiurus platycephalus	3	164.7	Jan.	0.1	0.3	-6.5	3.8	0.9	4.8	13	34
" "	1	163.8	Dec.	0.2	0.3	3.7	4.3	27	27	-100	250
Ictalurus catus	1	164.7	Jan.	0.4	0.6	1.1	4.9	-3.3	4.5	-67	110
Ictalurus lacustris	5	164.7	Jan.	0.2	0.3	2.9	2.2	-2.7	1.9	-13	23
" "	5	164.7	Jan.	0.2	0.3	2.5	2.2	-1.4	2.0	-6	22
" "	10	163.8	Dec.	0.1	0.4	2.1	4.4	8	22	130	260
Ameiurus platycephalus	2	154.7	Dec.	0.2	0.4	8.3	4.3	31	27	75	260
Ictalurus catus	1	154.7	Dec.	0.1	0.3	-0.3	4.5	19	27	6	250
Ictalurus lacustris	6	155.8	Dec.	-0.1	0.4	-0.9	4.1	18	28	80	250
" "	10	154.7	Jan.	0.4	0.5	3.3	4.3	19	25	25	260
Ameiurus platycephalus	1	137.5	Jan.	0.2	0.4	1.1	5.9	-11	22	-140	250
" "	1	136.4	Jan.	0.2	0.4	-1.1	5.6	-3	21	220	240
Ictalurus catus	1	137.5	Dec.	0.2	0.3	11.6	4.5	27	32	220	110
Ictalurus lacustris	2	137.5	Jan.	-0.1	0.4	3.6	6.9	11	23	6	250
" "	8	136.4	Jan.	0.1	0.4	-0.7	7.2	-11	22	-360	250
Composite B	7		Jan.					2.7	2.7	-5	20
Sunfish (Bass) Family											
Micropterus salmoides	2	146.4	Jan.	-0.1	0.3	-2.3	2.2	-	-	-	-

Note: (1) Per gram of tissue. (2) Per gram of ignited bone.

Table 9

The Radioactivity of Fresh Water Minnows and Algae

Savannah River 1951-1952

Specimen		Station River Mile	Month Collected	Radioactivity*			
Kind	Numbers per Sample			Alpha μμc/g±μμc/g		Beta μμc/g±μμc/g	
Minnows							
Hybognathus nuchalis	5	167.7	Jan.	0.6	0.3	3.2	2.5
" "	5	167.7	Jan.	0.3	0.3	1.4	2.4
Notropis hudsonius	2	167.7	Jan.	2.6	1.0	2.8	4.7
" "	2	167.7	Jan.	3.2	1.1	8.7	5.0
" "	1	167.7	Jan.	0.8	1.6	4.0	9.5
" "	5	167.7	Jan.	0.7	0.4	4.9	2.5
Notropis sp.	10	148.3	Jan.	-0.1	0.2	8.1	2.8
Algae							
Vaucheria sp.		171.6	Jan.	0.4	1.3	7.9	15.3
Stigeoclonium sp.		165.4	Jan.	-0.5	0.6	13.4	5.4
Vaucheria sp.		165.4	Jan.	-0.1	0.7	0.8	8.2
Audouinella sp.		165.4	Jan.	-0.4	0.6	14.3	5.6
Algae		148.8	Jan.	3.4	3.6	-9.3	27.1

Note: *Per gram of whole fish or moist (blotted) sample.

Table 10

The Radioactivity of Fresh Water Brush Box Organisms

Savannah River 1951-1952

Specimen		Month Collected	Radioactivity**			
Kind	Station*		Alpha $\mu\mu c/g \pm \mu\mu c/g$		Beta $\mu\mu c/g \pm \mu\mu c/g$	
Aquatic earthworms, (annelida)	Fo	Dec.	6.4	11.2	-25	109
Beetles (coleoptera)	UTR	Dec.	47	28	156	217
Fly larvae						
Diptera (Two winged)	Fo	Dec.	0.0	20	-129	187
"	UTR	Dec.	1.8	3.8	6.7	37
"	UTR	Nov.	8.0	12.0	33	134
Ephemerida (Mayflies)	Fo	Dec.	-0.4	2.5	-8.9	30.6
"	UTR	Dec.	1.3	1.6	4.7	13.9
"	UTR	Nov.	1.3	1.7	7.3	15.8
Neuroptera (Lace-wings)	UTR	Dec.	1.6	0.9	8.6	5.7
"	163.8	Dec.	0.5	0.5	0.6	4.0
Odonata (Dragonflies)	UTR	Nov.	2.6	2.1	1.3	17.2
Plecoptera (Stone flies)	UTR	Dec.	0.3	0.7	-5	5.4
"	163.8	Dec.	0.2	2.5	3.1	30
Trichoptera (Caddis flies)	Fo	Dec.	3.9	4.7	-23.1	39.2
"	UTR	Dec.	4.8	3.9	11.5	32
"	163.8	Dec.	0.3	0.6	3.9	5.5
"	UTR	Nov.	3.1	2.4	7.8	19.0

Note: * Four Mile Creek (Fo). Upper Three Runs (UTR).
** Per gram of moist (blotted) sample.

The Radioactivity of Estuarine Biota

In April 1952, 438 samples of crabs, shrimps, oysters and fishes were collected and shipped to Cincinnati. The flesh samples were processed for counting in a similar manner to the fresh water samples except that larger samples amounting to as much as 5 grams of tissue were taken for analysis to improve the counting statistics of the test with only a slight loss in the efficiency of counting due to self-absorption.

The results of 9 composite flesh samples representing 43 specimen of Blue crab and 3 composite shell or claw samples representing 15 specimen collected from five areas at the mouth of the Savannah River are presented in Table 11. The radioactivity of the fleshy tissue of 8 composite samples of shrimp from 40 specimen and 2 composite samples of oysters from 10 specimen are also presented in Table 11.

The results of 32 composite flesh samples of fishes representing 135 specimen are presented in Table 12. Also included in Table 12 are the results of 14composite bone samples from 62 specimen of fishes. The bone and shell samples of the estuarine samples were not entirely free of muscle tissue when they were processed according to the procedure given for fresh water bony tissue.

Considering the results in Tables 11 and 12, the maximum alpha activity in flesh tissue was 0.19 $\pm$ 0.006 $\mu\mu c/g.$ in an oyster sample. All but one composite estuarine flesh sample had a small but significant beta activity which may be attributed to K^{40} from salt water. The beta activity varied from 0.5 $\pm$ 0.2 $\mu\mu c/g.$ in an oyster sample to 4.5 $\pm$ 1.1 $\mu\mu c/g.$ in a fish sample. Except for one sample the alpha activity of bony tissue was less than the precision of the assay which varied from $\pm$ 2.4 to $\pm$ 15.7 $\mu\mu c/g.$ of bone ash. Similarly the beta activity of bony tissue was less than the precision of the assay which varied from $\pm$ 21 to $\pm$ 110 $\mu\mu c/g.$ of bone ash.

A resume of the maximum background radioactivity of samples collected from the Savannah River in the 1951-1952 HHC survey are presented in Table 13. The results show that the radioactive density of biological tissues is substantially greater than the radioactive density of the water which provides a habitat for the biota.

Minimum Detectable Radioactivity

Due to the statistical fluctuation of counting, the minimum detectable sample radioactivity (at a 95 percent confidence level) is taken to be equal to twice the standard deviation of the net counting rate of the sample prior to the application of correction factors for backscatter and self-absorption. The over-all efficiency of counting in a 2 pi chamber was found to be 51 percent for alpha activity and 73 percent for beta activity, as determined with the use of uranium and phosphorous^{32} standards.

Table II

The Radioactivity of Crabs, Oysters and Shrimp

Found in Savannah River Estuaries April 1952

Specimen			Radioactivity of Flesh(1)				Radioactivity of Shell(2)			
Kind	Numbers per Sample	Station*	Alpha μμc/g±μμc/g		Beta μμc/g±μμc/g		Alpha μμc/g±μμc/g		Beta μμc/g±μμc/g	
Crustacae										
Callinectes sapidus, (Blue crab)	5	A	0.04	0.06	2.3	0.5	0.5	2.9	-12	28
" "	5	A	0.04	0.06	2.0	0.4	2.2	3.2	-72	27
" "	4	B	-0.04	0.15	2.3	1.1				
" "	5	B	-0.11	0.11	3.0	0.9				
" "	4	B	0.02	0.13	2.2	0.9				
" "	5	C-D	0.11	0.16	2.3	1.0	1.0	5.7	-33	37
" "	5	D	0.01	0.14	2.1	1.0				
" "	5	E	-0.11	0.12	3.0	1.0				
" "	5	E	-0.02	0.16	2.0	1.0				
Penaeus setiferus, (Shrimp)	5	A	0.03	0.07	1.6	0.5				
"	5	A	0.03	0.07	1.6	0.5				
"	5	A	0.00	0.07	1.8	0.5				
"	5	B	-0.02	0.08	2.3	0.5				
"	5	B	-0.02	0.08	2.4	0.6				
"	5	C	0.09	0.06	2.2	0.5				
"	5	C	0.04	0.05	2.6	0.5				
"	5	D	0.00	0.07	1.8	0.5				
Mollusca										
Ostrea virginica, (Oyster)	5	A	0.19	0.06	0.9	0.2				
"	5	A	0.13	0.05	0.5	0.2				

Note: *Mouth of Savannah River off Savannah Beach (A), Off Long Island at midlength (B), at Fields Cut (C), near mouth of Wilmington and Skidaway Rivers (D), Wassaw Sound off Cabbage Island (E).

(1) Per gram of flesh.

(2) Per gram of ignited shell or claw.

Table 12

The Radioactivity of Fish Found in the

Savannah River Estuaries April 22-24, 1952

Specimen		Station*	Radioactivity of Flesh(1)				Radioactivity of Bone(2)			
Kind	Numbers per Sample		Alpha μμc/g ± μμc/g		Beta μμc/g ± μμc/g		Alpha μμc/g ± μμc/g		Beta μμc/g ± μμc/g	
Phycis regius (Hake)	3	A	-0.03	0.06	2.4	0.4	-4.4	15.7	-230	110
" "	3	A	0.02	0.14	1.4	0.7	-2.8	4.4	-31	36
" "	3	B	0.00	0.10	3.4	0.8	1.8	5.7	-28	37
Brevoortia smithi, (Menhaden)	5	A	0.22	0.17	4.5	1.1	-3.1	2.4	-39	26
"	5	A	-0.01	0.09	2.8	0.6	-1.1	2.7	-9	22
"	5	A+D	0.08	0.07	3.4	0.5	-	-	-	-
"	5	C+E	0.01	0.05	3.0	0.5	-	-	-	-
Bairdella chrysura, (Silver perch)	6	A	-0.06	0.10	2.4	0.8	-	-	-	-
" "	4	C	0.04	0.08	1.9	0.6	-	-	-	-
" "	5	C	0.06	0.07	2.2	0.5	-	-	-	-
" "	5	D	-0.02	0.06	2.6	0.5	-	-	-	-
" "	4	D	-0.03	0.08	1.9	0.5	-	-	-	-
" "	5	E	0.03	0.05	3.0	0.8	1.7	3.9	-43	27
" "	5	E	0.05	0.05	2.7	0.5	0.3	2.9	-16	21
Leiostomus xanthurus (Spotted croaker)	5	A	0.03	0.07	2.2	0.5	-0.3	2.5	-42	22
" "	5	A	0.01	0.07	2.5	0.5	-0.3	2.5	-56	21
" "	5	B	0.09	0.07	2.3	0.5	-	-	-	-
" "	4	D	0.03	0.10	2.3	0.6	-	-	-	-
" "	4	D	0.03	0.10	1.8	0.6	-	-	-	-
" "	5	E	-0.06	0.07	1.9	0.5	4.1	3.4	-3	21
" "	5	E	-0.07	0.07	2.0	0.5	0.0	2.7	-3	21

Table 12 (Cont'd)

The Radioactivity of Fish Found in the

Savannah River Estuaries April 22-24, 1952

Specimen			Radioactivity of Flesh(1)				Radioactivity of Bone(2)			
Kind	Numbers per Sample	Station*	Alpha μμc/g ± μμc/g		Beta μμc/g ± μμc/g		Alpha μμc/g ± μμc/g		Beta μμc/g ± μμc/g	
Menticerrhus americanus, (King croaker)	4	A	0.08	0.07	2.8	0.5	-2.0	11.2	-57	83
Micropogon undulatus, (croaker)	3	D	-0.01	0.04	1.7	0.4	-	-	-	-
"	3	D	0.00	0.04	1.8	0.4	-	-	-	-
Peprilus paru, (Harvest fish)	5	A	0.22	0.31	2.3	2.3	1.2	3.2	-12.2	21.8
" "	4	A	0.23	0.38	2.9	2.9	2.2	4.8	-12.5	32.8
" "	3	A+D	0.13	0.10	2.9	0.8	-	-	-	-
" "	4	B	0.05	0.08	3.0	0.6	-	-	-	-
" "	4	B	0.06	0.08	2.8	0.6	-	-	-	-
" "	4	D	0.06	0.11	1.7	0.6	-	-	-	-
" "	4	D	0.10	0.11	1.5	0.7	-	-	-	-
Cynoscion regalis, (Weak fish)	1	E	0.04	0.13	2.2	0.9	-	-	-	-

Note: *Mouth of Savannah River off Savannah Beach (A), Off Long Island at midlength (B), at Fields Cut (C), near mouth of Wilmington and Skidaway Rivers (D), Wassaw Sound off Cabbage Island (E).

(1) Per gram of flesh.

(2) Per gram of ignited bone.

Table 13

The Maximum Radioactive Density

of the Savannah River Samples

1951-1952

Sample type	Alpha Radioactivity		Beta Radioactivity	
	μμc/g	± μμc/g	μμc/g	± μμc/g
Fresh Water				
In suspended solids	0.0041*	0.0017	0.0132*	0.0006
In dissolved solids	0.0084*	0.0021	0.0318*	0.0148
Fresh Water Organisms				
Fish Flesh	1.5	0.9	11.6	4.5
Minnows (whole fish)	3.2	1.1	8.7	5.0
Fly larvae	4.8	3.9	8.6	5.7
Algae	3.4	3.6	14.3	5.6
Estuarine Organisms				
Crab flesh	0.11	0.16	3.0	0.9
Shrimp flesh	0.09	0.06	2.6	0.5
Oyster flesh	0.19	0.06	0.9	0.2
Fish flesh	0.22	0.17	4.5	0.6

Note: *Per milliliter of water.

Suppose the instrument background for alpha counting is 0.32 cpm (counts per minute) and for beta 64 cpm, then the minimum detectable sample radioactivity would be 0.3 μμc for alpha and 2.5 μμc for beta radioactivity. The minimum detectable radioactivity per liter or gram depends on the size of the sample taken. The minimum detectable level of alpha and beta activity for a given sample type and size is as follows:

	Sample Size	Alpha	Beta
Water Samples			
Suspended Solids	0.5 liters	0.6 μμc/liter	5.0 μμc/liter
Dissolved Solids	0.2 liters	1.5 μμc/liter	12.5 μμc/liter
Biological Samples			
Flesh	200 mg.	1.5 μμc/g.	12.5 μμc/g.
Flesh	400 mg.	0.75 μμc/g.	6.2 μμc/g.
Flesh	750 mg.	0.53 μμc/g.	4.3 μμc/g.
Flesh	2,000 mg.	0.15 μμc/g.	1.25 μμc/g.
Bone Ash	20 mg.	15 μμc/g.	125 μμc/g.
Bone Ash	40 mg.	7.5 μμc/g.	62 μμc/g.

Obviously, when dealing with low level radioactive samples in the order of the minimum detectable amount, the observed count, because of statistical fluctuations, may be lower than the observed background. This gives rise to negative radioactive values. This is to be expected and indicates that the precision of the determination is poor in the low level range.

The Radioactive Elements in Background Measurements.

The background radioactive elements measured include the isotopes of the uranium and thorium series and natural beta emitting isotopes such as K^{40}, but probably excludes the radon group. The assay would also include artificially produced isotopes which had not decayed prior to analysis. In this connection, 10 water samples were assayed within 2 weeks of collection, 23 were assayed within one month and the remaining nine within four months.

About forty percent of the biological samples of flesh of fresh water organisms were analyzed during the first month, an additional 40 percent were analyzed during the next two months, and the remainder in six to seven months. One half of the bone samples of fresh water fish were analyzed within one month of collection and the remainder after 8 to 10 months. The estuarine biological samples were analyzed 5 to 6 months after collection.

Summary of the Radioactive Background

Studies of the Savannah River

Thirty-two water samples from seven Savannah River sampling stations and four tributaries were analyzed for the gross alpha and beta radioactivity associated with the suspended solids (insoluble) and in solution (soluble). The insoluble alpha activity varies from zero to a maximum of 4.1 ± 1.7 micro-microcuries per liter of water. The soluble alpha activity of the sample showing the maximum insoluble activity was 0.1 ± 1.1 μμc/liter. Thus the total alpha activity was 4.2 ± 2.0 μμc/liter of water. Usually there was more insoluble than soluble alpha activity in the samples. However, in six out of 31 samples the soluble alpha activity exceeded the insoluble activity. The maximum soluble alpha activity was 8.4 ± 2.1 μμc/l. compared to an insoluble alpha activity of 0.4 μμc/l.

The beta activity was appreciably higher in magnitude than the alpha activity. This is particularly true with respect to soluble activity. Thus one sample had a soluble beta activity of 23.1 ± 9.8 μμc/l. with an insoluble beta activity of only 0.2 ± 4.4 μμc/l. The maximum total beta activity found in any sample was 40.4 ± 15.6 μμc/l. of which 31.8 ± 14.8 μμc/l. was in solution.

Radioactive measurements were determined on 71 fresh water biological samples. These samples consisted of the flesh and bony tissues of 40 individual or composite fish samples, 7 composite samples of minnows, 7 samples of brush box organisms (largely fly larvae), and 7 samples of algae. The results showed that the radioactivity of all samples exclusive of fish bone, was 4.8 ± 3.9 μμc or less of alpha activity per gram of wet weight sample. On these samples the beta activity was 14.3 ± 5.6 μμc or less per gram of wet weight sample. The minnows (whole fish samples) and the fly larvae, all of which probably contained native soil, showed a significant alpha activity. The algae showed no significant amount of alpha activity, but a measurable beta activity. The maximum alpha activity of fish flesh was 1.5 ± 0.9 μμc/g. The radioactivity of the ash of fish bone was less than the statistical error of the determination which varied from ± 2 to 28 μμc/gram for the alpha activity and ± 20 to 260 μμc/g. for beta activity.

Estuarine biological samples from five sampling stations were collected from tidal waters at the mouth of the Savannah River April 22-24, 1952. Radioactive analyses were made on samples of flesh tissue which included 9 composite samples of crabs, 6 of shrimps, 2 of oysters, and 32 of fishes; and the bone or shell of 17 composite samples from the various groups. The maximum alpha activity in flesh tissues was 0.19 ± 0.06 μμc/g. in an oyster sample. All but one composite flesh sample had a small but significant beta activity which may be attributed to K^{40} from salt water. The beta activity varied from 0.5 ± 0.2 μμc/g. in an oyster sample to 4.5 ± 1.1 μμc/g. in a fish sample.

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